

## REPORT DOCUMENTATION PAGE

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Final Technical Report on  
Defense University Research Instrumentation Grant  
**Scanning Probe Microscope**

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This DURIP allowed us to purchase a Digital Instruments Dimension 3100 Atomic Force Microscope (AFM), which is a versatile tool that can serve dual functions, both as an AFM and a scanning-tunneling microscope (STM). The AFM and the STM are separate units and are mounted on two different stages both of which minimize external noise and vibration. Within the purview of each of these units lie several modes of imaging. As an AFM, imaging is done in two modes namely the tapping mode and the contact mode. These modes have the capability of resolving step heights of a few angstroms and have a lateral resolution of a nanometer. As an STM it has the ability to image atoms. This can be done in several ways depending upon the kind of atoms that one is imaging. The atomic forces exerted on the tip can be electrostatic, magnetic or purely mechanical. In its several modes of operation as an STM, the instrument uses one of these forces as data to obtain atomic level resolution. Powerful software packages that allow for data manipulation of the fourier spectrum help sharpen the collected data. One other use of the AFM arises from its use in the tapping mode. The tapping mode requires the use of a silicon cantilever that is vibrated at its resonant frequency as it scans the surface. This requires tuning of the cantilever, which is done by the instrument. This enables the AFM to be used as a tuning device for cantilevers fabricated for other applications.

This AFM is proving to be a very versatile tool that has become a very useful resource at Purdue University. It is being used for the research programs of Prof. Melloch, Janes, Datta, Reifenberger, Capano, Neudeck, and Bashir as described below.

Samples prepared by Mike Capano's group were examined using contact mode AFM for surface topography. The interest was a comparison of anneal processes on aluminum or titanium/aluminum on silicon carbide.

The tapping mode AFM was used to investigate the silicon growth of microstructures for Gerold Neudeck's group. In this case, care was taken to investigate the top facets of silicon growth as well as the smoothness of the structure sides.

The Dimension 3100 AFM is also being used for electrostatic force microscopy to support the work of David Janes, Supriyo Datta, and Ron Reifenberger. Self-assembled monolayers of various molecules formed on flat gold surfaces are investigated using electrostatic forces measurements. These measurements are expected to provide insight into the bonding type/strength of molecules to surfaces for use in molecular electronics. The DI Multimode AFM will also have significant application in this area.

A unique application for the Dimension 3100 is to measure the resonant frequency of cantilevers prepared by Prof. Bashir's group. Here the AFM is not used as a typical AFM but rather the capabilities of the laser and photo diode are exploited to measure the cantilever resonant frequency. The standard XY stage of the AFM has been replaced with a custom built stage, which provides the correct geometry to reflect the laser signal off the cantilever substrate back to the photodiode without a typical tip holder in the path. Additional modifications included the rerouting of AFM signals for drive frequencies and data acquisition.

Prof. Melloch's group is using the AFM for imaging the surface features of wide-bandgap semiconductors such as silicon carbide (SiC) and Gallium Nitride (GaN) which are grown

on silicon substrates by Metal Organic Chemical Vapor Deposition (MOCVD). The effect of the growth conditions on the surface morphology of the epi-layers is monitored and the growth conditions adjusted to get a smooth surface. Examples of two AFM scans are shown below. Figure 1 is the 3D view of the surface scan of a GaN film grown directly on silicon using an aluminum nitride (AlN) buffer, while figure 2 is the 2D view of the surface scan of a thicker GaN film grown on a composite SiC/AlN buffer on silicon. Features such as the hexagonal columnar structure can be resolved as seen in figure 2. These are indicative of the film polarity and affect the behavior of devices fabricated on these materials. These make the AFM a valuable characterization tool for optimizing the growth process.

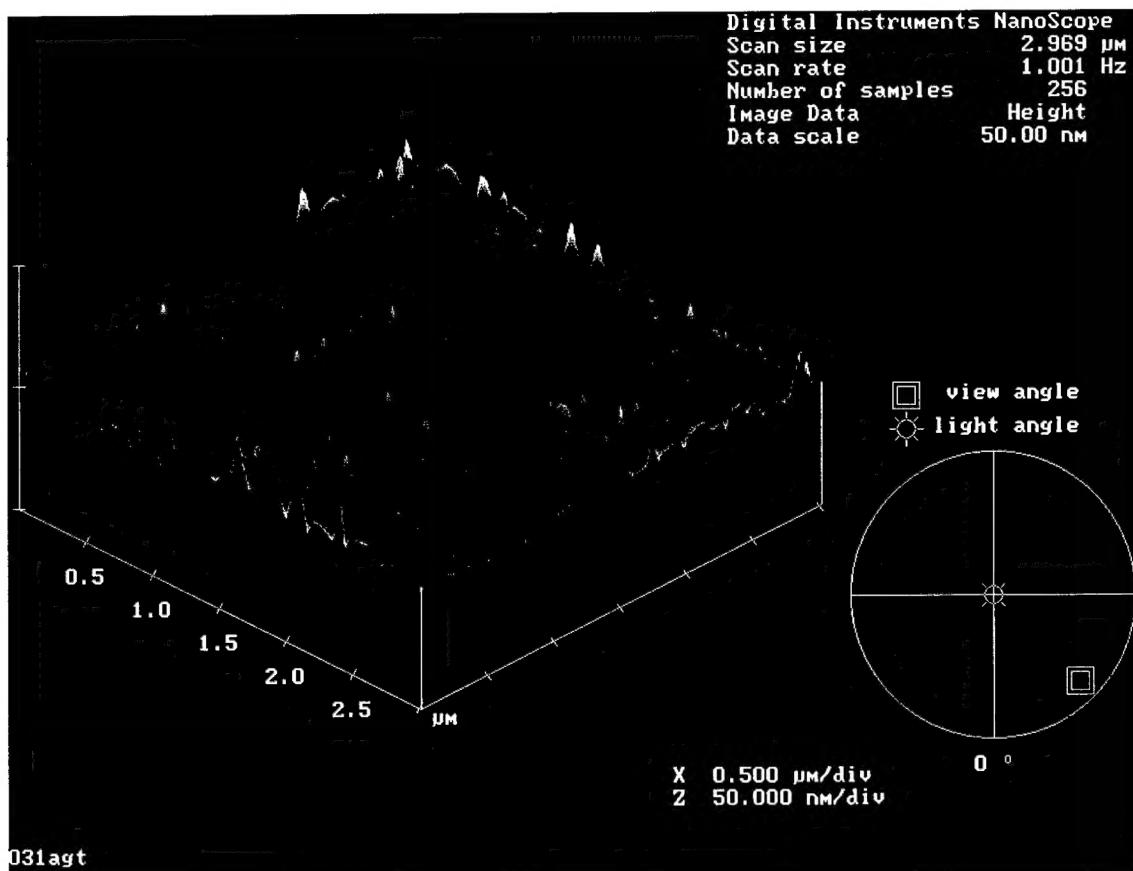


Figure 1 : A 3D view of the surface of GaN grown on AlN buffered Si.

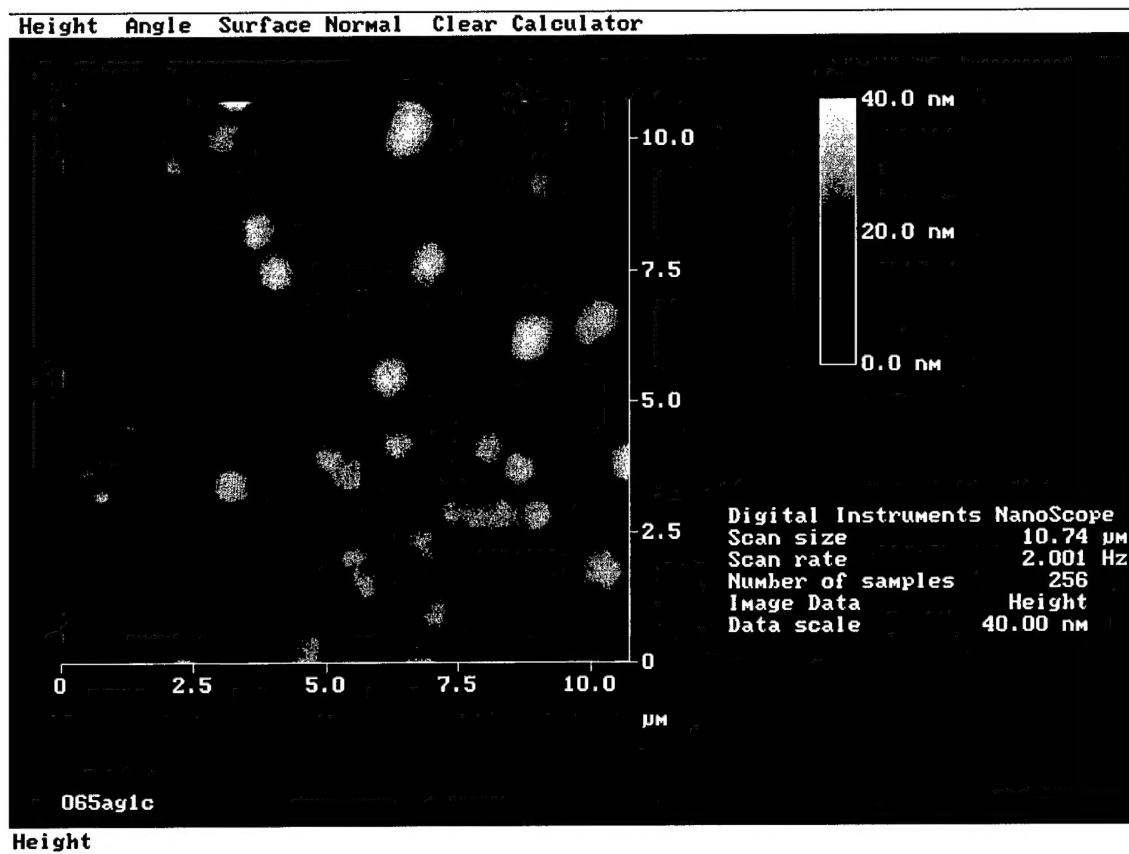


Figure 2 : A 2D view of the GaN surface grown on AlN/SiC buffered Si.